Operational Domain Systems Engineering

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Introduction

Recently in the INCOSE Insight, Fellow's Edition, Jeffrey O. Grady [1] discussed Robert E. Machol's 1965 concept of the "T-Shaped" domain knowledge of the systems engineer. He challenged that in reality, most systems engineers are somewhat broader in knowledge than just their core discipline. In effect, there is a movement to become "domain" systems engineers with general knowledge of the various technical specialties that contribute to that field. While much has been written on requirements analysis, subtle variations in describing a problem can still have major impacts on the potential solutions being sought or the usefulness of the solution selected. Underestimating the value of operational domain knowledge, or not being able to effectively convey the knowledge can lead a project towards a poor or suboptimal solution. This gives rise to the concept of operational domain systems engineering knowledge.

Operational Domain Systems Engineering Knowledge

A slight refinement beyond technical or engineering domain knowledge is proposed, which includes operational knowledge and experience. This can be labeled operational domain systems engineering. The ability to accurately comprehend and express the important factors within a problem space as well as to accurately judge potential usefulness absolutely relies on such operational understanding and experience. This is quite different from design knowledge. For example, few aeronautical engineers have actually piloted the final produced aircraft. Systems are created for use and those that are involved in the day to day engineering design trade decisions rarely use or maintain the systems they develop.

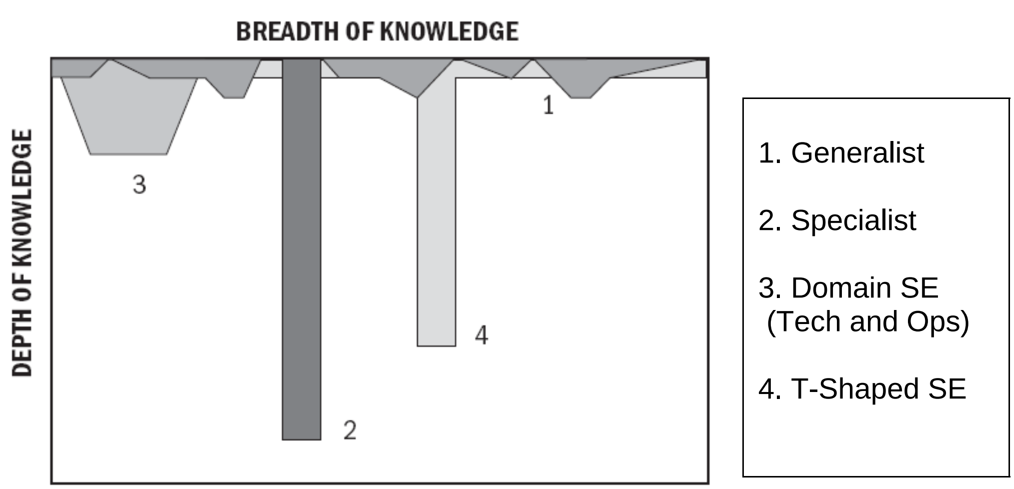

Figure 1: Knowledge Spaces [1]

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Region of Effective Communication

The relationship between users, systems engineers, and sub-system design engineers is the foundation for developing a useful system. Not only must the three parties cooperate in order to effectively translate requirements to specifications, they must continue to interact during the trades made throughout detailed sub-system design and integration. The Region of Effective Communication (REC), shown in Figure 2 represents the ability of team members from each perspective to communicate and evaluate choices to make optimum system level decisions. A lack of constructive interaction between the three parties can lead to an ineffective system solution. As each of the three groups gains a better understanding of the other two, the interaction becomes more effective, moving into the Region of Effective Communication. Systems engineers, having typically developed out of a technical engineering field (aeronautical, mechanical, electrical, software, etc.), are well suited to communicate with sub-system design engineers during a development project. The communication between engineers and users is often more difficult. One way to improve the interaction between these parties is to employ systems engineers with experience in the operational community – operational domain systems engineers.

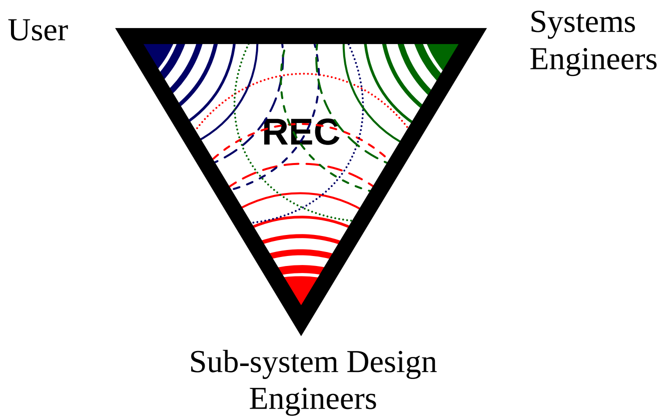

Figure 2. Region of Effective Communication (REC)

Historical Case Study

Executed during the late 1970's, The Pave Low III program involved the modification of an Air Force combat rescue helicopter intended to rescue downed pilots during Vietnam. Technology was required to overcome the operational challenges presented by night operations before the introduction of the night vision devices now common among military aviators. The problem space involved requirements to successfully navigate, avoid terrain, visually locate downed pilots and maintain aircraft control without outside visual references. At that time, any solution had to include multiple components that addressed parts of the problem as well as provide integrated system level performance for the overall mission task. The program had failed twice previously as it wrestled with cost versus benefit in developing a useful solution to the problem. During the third attempt, the development organization (System Program Office) recognized the need for an experienced operator (pilot) with an engineering background to

participate in the development. By developing and prioritizing requirements, interacting with the technical engineering team during the design, and planning for test and evaluation, this operator, Lt Col Frank Pehr, fulfilled several critical systems engineering functions. In the words of the Chief Engineer [2], "His efforts, probably more than any other individual's, made the [Pave Low III] operationally successful. He recognized both [user] needs and the [acquisition engineering] problems". Lt Col Pehr effectively bridged the gap between the user community and the technical engineers and maintained a focus on end usefulness for the entire team throughout the development.

Recent Observations

In the early stage of the system lifecycle, the role of the operational domain systems engineering appears most useful. Observations during several sponsored projects confirm extremely effective application of the early Systems Engineering process, when military operators (predominantly pilots) are trained in Systems Engineering and given large complex, military-related problems.

During one project, we supported a project to reduce helicopter mishaps in dusty environments such as Afghanistan and Iraq. These aircraft are susceptible to re-circulating dust in arid desert regions that reduce visibility and significantly increasing the risk of aircraft mishap during low altitude hover, landing and takeoff; this is called "brownout". Numerous sensors were evaluated to determine their applicability to seeing through brownout. Initially, many sensor engineers/ technologists assumed the ability to detect objects through the dust equated to a successful system solution. For example, technologies such as millimeter wave radar show promise in penetrating visual obscurants, but lack the resolution required to make good decisions during landing. Due to the efforts of the operational domain systems engineers, they were able to convey to the entire team that the integrated solution hinged on the ability to maintain aircraft control, more than merely detecting objects through a dust cloud. Maintaining situational awareness of the hazards surrounding the aircraft is important and could be aided by sensor information, but is a secondary consideration to safely control the aircraft.

Other recent examples include the development of Special Operations Forces Air (SOFAir) Mission Planning Enterprise architecture, when designed by a Systems Engineering team including a SOF helicopter pilot. Another group of four F-15E "Strike Eagle" pilots performed concept refinement, simulation and analysis for improved time sensitive targeting, using Weapon-borne Battle Damage Assessment techniques. Lastly, two F-15C pilots provided a strong systems engineering team in optimizing capability by selecting various modifications for the extended life of the F-15C fleet. While these examples have been defense-related, it is envisioned that operational domain knowledge would be beneficial in early commercial lifecycles also.

Conclusion

The chasm separating the developers of a new system and the operators who will employ it, often leads to reduced overall system effectiveness (even though the system may meet all designated system performance specifications). Perhaps the best way to ensure end "usefulness"

during the development of a new system is to employ systems engineers with actual operational experience (both using and maintaining related systems) in the problem domain. To the extent that the system engineer can possess operational knowledge, this would certainly amplify their utility in the early development work [3]. This concept is termed operational domain systems engineering knowledge, refining Jeffrey O. Grady's Systems Engineering knowledge concept [1].

References

1. Jeffrey O. Grady, "The Ultimate Foundation of Systems Engineering". INCOSE INSIGHT: Fellows Edition, Vol 8, Issue 2, March 2006.
2. Leo Gambone, "Pave Low III, That Others May Live". USAF Aeronautical Systems Division History Office, pg 68-69, April 1988.
3. Jeffrey Grady, personal communication, May 2006.